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Cultural Studies on Carrot Stecklings in Relation to Seed Production

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United States Department of Agriculture, Bureau of Plant Industry, Soils, and Agricultural Engineering, in cooperation with the Utah Agricultural Experiment Station

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INTRODUCTION

CARROT SEED is usually produced by first growing and harvesting a crop of mother roots, called stecklings. Selected stecklings are then either replanted immediately or, if the winters are severe, placed in storage and replanted in the spring. This procedure is commonly known as the root-to-seed method.

The increase from a given amount of seed depends on many factors, including the number and size of stecklings obtained for planting, facilities available for their storage, methods of planting them, and management of the crop after planting. Time of harvest and quality of seed, in addition to yield of seed, are important considerations.

Under commercial conditions in the Intermountain States, the average grower prefers a medium-size steckling, one that is 1 to 1½ inches in diameter. Whatever the size preferred, the stecklings should be ready to harvest in the fall only when the ground from which they are taken and the storage cellar into which they are placed have cooled to a temperature suitable for storage. In most districts, if the seed

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for a steckling crop is sown in early spring, the resulting roots will be much too large by fall. Although large stecklings may each produce more seed than small ones or have other desirable characteristics, they tend to crack. Furthermore, the increase in seed production of large stecklings is not in proportion to their size. A given number require more storage space than the same number of smaller ones, and so growers tend to avoid them.

Experiments to determine how much the time of planting and the rate of seeding affect the number and size of stecklings produced, and to provide answers to related questions of growers were conducted at the Utah Agricultural Experiment Station from 1945 to 1948.

The stecklings produced in the experiments, with others grown in the same field under similar conditions, were used in another series of experiments, from 1945 to 1949, to determine the effect of steckling size on the yield and quality of seed. Tests to determine the importance of time of seed harvest were included. In addition to information on yields and viability of seed, data were collected on the effect of various treatments on the height and branching habit of the plants, on the rate of growth of the inflorescence, and on the proportion of flowers that set seed.

A hailstorm on July 24, 1948, seriously injured all the experimental plantings. The storm, which lasted for about half an hour, defoliated most of the carrot plants and broke or injured many of the seed heads. Although much of the seed had set and some was well developed, there was little shattering. Defoliation was probably the most serious damage. Carrot plants in all experiments and treatments of 1948 continued to mature more or less normally despite their injuries. Although yields undoubtedly were cut by perhaps 40 or 50 percent, the data from some experiments still showed differences of statistical significance, and so yields and other data for 1948 are presented with those of other years.

STECKLING PRODUCTION

METHODS

A Planet Jr., Model 300A, planter fitted with the usual narrow planting shoe, was used in most of the experimental plantings. The plates of this commercial planter with their wide range of graduated openings allow for a great variety of seeding rates and also make it possible to repeat any of them exactly.

In 1945, the rows were spaced 18 inches apart. Heavy rains several times packed the ground after planting but before emergence of the seedlings. More frequent irrigation than normal was necessary to keep the soil surface moist and thus allow the seedlings to come through; even then, stands were not uniform enough for good experimental conditions. In the years following, in order to facilitate irrigation and improve stands, the spacing between the rows was reduced to 12 inches, except in the width-of-planting-shoe tests. As a result, stands were much more satisfactory for experimental purposes. Because of poor stand in 1945 no data are presented on sizes and numbers of stecklings harvested.

Plots consisted of single rows 50 feet long, except in the time-of-planting experiment, when they consisted of three rows, the center one being used for record purposes. Planter-plate opening No. 10, giving a rate of approximately 8.4 pounds of seed per acre with rows 1 foot apart and 5.6 pounds at 1½ feet, was used in all experiments except the rate-of-seeding test.

To avoid the effects of loss in stand from any condition other than that of treatment, only 25 feet of each plot was used for data. This length gave an ample number of stecklings to be graded and counted.

In the time-of-planting test, the interval between sowings was successively reduced through the first 3 years. Three sowings were made each year. In 1945, sowings were made at approximately monthly intervals, beginning June 1. In the following year, the interval was reduced to about 3 weeks, with the first planting on June 4. In 1947 and 1948, the interval was cut to 2 weeks, with the first sowings on June 18 and 10, respectively.

Planter-plate openings Nos. 7, 8, 9, 11, and 13 were used for the seeding in 1945 and 1946. They were changed to Nos. 7, 9, 11, 13, and 14 for the years 1947 and 1948. In 1945, when the rows were 18 inches apart, the holes resulted in seeding rates, in pounds per acre, of 2.3, 3.0, 4.4, 7.3, and 9.3, respectively. The rates for 1946, 1947, and 1948, when the rows were 12 inches apart, are given in table 1.

The standard narrow planting shoe sows seed in a furrow slightly wider than half an inch. Shoes that are flanged to make a wider furrow are available in 2- and 4-inch widths. Seed falling from the hopper into the wider shoes strikes a baffle and is scattered. In the width-of-shoe test, planter-plate opening No. 10 was used in all treatments, sowing 5.6 pounds of seed per acre. A row width of 18 inches was necessary in this test; otherwise, in the 4-inch treatment only about 8 inches would be left between the outermost plants in the adjacent rows.

Stecklings in all the experimental plots were harvested within a period of about a week in late October or early November, shortly before the onset of winter weather. The stecklings were collected in boxes and placed in a cellar, where later they were graded into various sizes.

Results

RATE OF SEEDING

Data obtained on the effect of rate of seeding on the number and size of carrot stecklings per acre (table 1) indicate that both the total number and the number of most usable roots (the medium and large sizes combined) increased noticeably with each increase in the rate of seeding. As the rate of seeding was stepped up from 3.4 to 13.9 pounds of seed each year, the number of most usable stecklings increased from 125,000 to 501,400 in 1946, from 380,300 to 786,300 in 1947, and from 291,400 to 644,600 in 1948. In 1947, when a rate of 17.9 pounds of seed per acre was added to the experiment, a still greater number of such stecklings was produced, but in 1948 this rate of seeding failed to produce as many roots as 13.9 pounds of seed.

All sizes of stecklings are usable in the sense that they will produce seed. This report shows, however, that medium-size and large stecklings are usually the most satisfactory for seed production. Growers occasionally are compelled to use other sizes, at least to some extent, because sufficient numbers of desirable sizes are not available. How the rate of seeding may influence the number in any of five sizes can be determined from the data in table 1.

TABLE 1.—*Effect of rate of seeding on number of carrot stecklings of different sizes per acre when sown in rows spaced 12 inches apart, 1946–1948* [1]

Seed per acre (pounds)	Seeder hole No.	Number of stecklings per acre harvested						
		Very small, <½ inch	Small, ½–1 inch	Medium, 1–1½ inches	Large, 1½–2 inches	Very large, >2 inches	Total, all sizes	Most usable sizes [2]
		Thousands	*Thousands*	*Thousands*	*Thousands*	*Thousands*	*Thousands*	*Thousands*
1946								
3.4	7	1.7	13.9	53.1	71.9	49.2	189.8	125.0
4.6	8	1.7	10.5	47.5	57.5	43.1	160.3	105.0
6.6	9	4.4	38.3	145.5	121.1	64.9	374.2	266.6
10.4	11	11.3	91.5	240.9	186.0	62.3	592.0	426.9
13.9	13	46.2	200.4	332.4	169.0	38.8	786.8	501.4
1947								
3.4	7	24.8	106.7	277.5	102.8	3.0	514.8	380.3
6.6	9	25.7	187.3	343.7	196.9	14.4	768.0	540.6
10.4	11	103.2	410.8	648.6	84.9	1.3	1,248.8	733.5
13.9	13	106.3	627.3	669.1	117.2	4.8	1,524.7	786.3
17.9	14	193.0	765.3	747.1	68.0	.9	1,774.3	815.1
1948								
3.4	7	13.1	75.8	207.3	84.1	12.6	392.9	291.4
6.6	9	28.3	191.7	323.7	92.3	13.9	649.9	416.0
10.4	11	68.0	421.2	506.2	79.3	0	1,074.7	585.5
13.9	13	108.0	510.5	553.6	91.0	3.0	1,266.1	644.6
17.9	14	83.6	544.9	548.4	63.2	.4	1,240.5	611.6

[1] An estimate of the number of 60-pound bags of stecklings produced by any of the treatments can be calculated by dividing the number of very small stecklings by 4,320, of small stecklings by 900, of medium-size stecklings by 360, of large stecklings by 150, and of very large stecklings by 105.

[2] Medium and large sizes combined.

On the basis of the number of stecklings harvested in 1947 and 1948, there tended to be fewer very large roots and more small and very small ones with every increase in rate of seeding. If any of the figures in table 1 are changed into a percentage of the total number, the variation in distribution becomes more apparent. In general, the proportion of medium-size stecklings in relation to total number remained stable in comparison to the percentage of roots falling into the other size classes. In 1946, the medium-size stecklings represented a range of 28 to 42 percent of the total; in 1947, from 42 to 54 percent; and in 1948, from 44 to 53 percent. In only two cases did the medium-size stecklings account for less than 30 percent of the total, and in only three cases, including the two just mentioned, did they account for less than 40 percent. All these exceptions occurred in 1946, when the total number of roots produced was lower than in the following years.

While the proportion of medium-size stecklings remained comparatively stable with every increase in the rate of seeding, the percentage of the large roots tended to decrease and that of the smaller ones to increase.

By dividing any of the numbers in table 1 by the factor 14,520, it is possible to determine how many acres each of the various groups would have planted if set 1 foot apart in rows spaced 3 feet apart. If consideration is limited to the most usable sizes (medium and large combined), then the acres possible to plant from an acre of seedbed planted at rates given in table 1 would have ranged from 9 to 34 in 1946, 26 to 56 in 1947, and 20 to 44 in 1948.

TIME OF PLANTING

Although stands were unsatisfactory in 1945, the size of steckling harvested in the fall definitely decreased as the time of planting was delayed. It appeared that a planting in early August, as in 1945, was entirely too late to be practicable; hence, in 1946, the interval between plantings was reduced from 4 to approximately 3 weeks.

The numbers and sizes of roots obtained in 1946 are shown in table 2. The stecklings of most usable size decreased from 522,700 to

TABLE 2.—*Effect of time of planting on number of carrot stecklings of different sizes per acre when sown in rows spaced 12 inches apart at a rate of 8.6 pounds per acre, 1946–48* [1]

Date of planting	Number of stecklings per acre harvested						
	Very small, <½ inch	Small, ½–1 inch	Medium, 1–1½ inches	Large, 1½–2 inches	Very large, >2 inches	Total, all sizes	Most usable sizes [2]
	Thousands	*Thousands*	*Thousands*	*Thousands*	*Thousands*	*Thousands*	*Thousands*
1946							
June 4	9.6	64.0	211.7	311.0	168.1	764.4	522.7
June 26	9.1	91.0	147.2	154.2	24.8	426.3	301.4
July 29	314.9	173.4	2.2	0	0	490.5	2.2
1947							
June 18	39.6	232.6	426.5	166.4	6.5	871.6	592.9
July 2	84.1	343.7	389.4	34.4	0	851.6	423.8
July 16	121.1	345.0	101.5	.4	0	568.0	101.9
1948							
June 10	49.2	235.2	311.9	91.5	8.3	696.1	403.4
June 24	35.3	125.5	159.9	29.2	3.0	352.9	189.1
July 8	17.9	75.8	84.5	5.2	0	183.4	89.7

[1] An estimate of the number of 60-pound bags of stecklings produced by any of the treatments can be calculated by dividing the number of very small stecklings by 4,320, of small stecklings by 900, of medium-size stecklings by 360, of large stecklings by 150, and of very large stecklings by 105.

[2] Medium and large sizes combined.

301,400 to 2,200 in successive plantings 3 weeks apart. There was a large preponderance of very small and small roots and no large or very large ones in the planting of July 29. Because the number of usable stecklings decreased so drastically when seed plantings were made 3 weeks apart, it was decided to plant only 2 weeks apart in 1947 and 1948.

No direct comparison can be made between the data of any 2 years in table 2, because the planting dates varied from year to year. The general pattern was the same in all 3 years. In every year, the number of most usable stecklings definitely became smaller as the date of planting became later. This occurred because weather and soil moisture between sowing and emergence became less favorable as summer advanced. In 1948 conditions were less favorable than usual, and the total stands were much below normal. The distribution of stecklings of the various sizes consequently followed a somewhat different pattern than in previous years. Aside from 1948, however, the number of very small stecklings in the first sowing of each year was small compared with the number in later seedings. For example, in 1947, an average year so far as these studies are concerned, when plantings were spaced at 2-week intervals, the numbers of very small stecklings ranged from 39,600 in the first planting, on June 18, to 121,100 roots in the third planting, on July 16. This represented a range of from 4.5 to 21.3 percent of the total number of stecklings produced that year. In contrast, the number and proportion of very large stecklings in the first plantings were greater than in the later plantings.

Seed growers have to think of a field for growing stecklings in terms of the seed-crop acreage that can be planted from it. Dividing any of the numbers of stecklings in table 2 by 14,520 gives the number of acres that could be set out at a spacing of 1 foot apart in 3-foot rows. The data indicate that there were enough stecklings of desirable size in the earliest planting time during the years 1946 to 1948, inclusive, to set out 27.8 to 40.8 acres from 1 acre of the steckling field. By sowing seed 3 to 4 weeks later, the average that would be transplanted with stecklings of the same size would have been from 20.7 acres in 1946 to 7.0 acres in 1947.

WIDTH OF PLANTER SHOE

Tests with the standard, the 2-inch, and the 4-inch planter shoes (table 3) showed no marked or consistent differences such as those shown in the tests on rate of planting. The total number and the number of most usable sizes of stecklings were roughly the same from the plantings made with the standard and the 2-inch shoes. Use of the 4-inch shoe, however, resulted consistently in the smallest total number of roots every year and, with few exceptions, the smallest number in each size group of roots each year. No important effect of shoe on the distribution of root sizes produced under these conditions was noted.

Table 3.—*Effect of width of planting shoe on number of carrot stecklings of different sizes per acre when sown in rows 18 inches apart, 1946–48*[1] [2]

Year and width of shoe	Number of stecklings per acre harvested						
	Very small, <½ inch	Small, ½–1 inch	Medium, 1–1½ inches	Large, 1½–2 inches	Very large, >2 inches	Total, all sizes	Most usable sizes [3]
	Thousands	*Thousands*	*Thousands*	*Thousands*	*Thousands*	*Thousands*	*Thousands*
1946							
Standard	3. 8	29. 0	68. 0	72. 3	40. 7	213. 8	140. 3
2-inch	2. 3	28. 8	79. 0	71. 4	42. 1	223. 6	150. 4
4-inch	1. 5	8. 7	34. 0	34. 8	40. 3	119. 3	68. 8
1947							
Standard	28. 5	123. 4	276. 5	190. 2	31. 4	650. 0	466. 7
2-inch	18. 6	101. 9	257. 9	205. 6	22. 9	606. 9	463. 5
4-inch	13. 4	75. 5	211. 4	159. 1	34. 8	494. 2	370. 5
1948							
Standard	13. 4	94. 1	231. 2	138. 8	13. 1	490. 6	370. 0
2-inch	14. 2	112. 1	273. 8	134. 5	9. 3	543. 9	408. 3
4-inch	15. 7	87. 1	217. 8	106. 6	9. 0	436. 2	324. 4

[1] An estimate of the number of 60-pound bags of stecklings produced by any of the treatments can be calculated by dividing the number of very small stecklings by 4,320, of small stecklings by 900, of medium-size stecklings by 360, of large stecklings by 150, and of very large stecklings by 105.

[2] Planter-plate opening No. 10 was used throughout, sowing 5.6 pounds of seed per acre.

[3] Medium and large sizes combined.

STECKLING STORAGE

Methods

For lack of a variety of controlled storage conditions, tests were limited to some simple observations on the results obtained from storing roots of different sizes in small and large containers, with and without sand, in a small cellar with an earthen floor. A vent brought cool air in at the floor level; there was another in the roof at the other end of the room. The temperature was kept between 32° and 40° F. in accordance with the recommendation of Platenius.[1]

Results

Data from the single storage experiment (table 4) show that all sizes of stecklings kept about equally well under the favorable storage conditions. Injury from decay was mostly limited to the remnants of petioles around the growing point. As most of the roots with some decay and many of the shriveled roots later grew into healthy, productive plants, the loss in storage was actually below 10 percent in nearly all treatments. The unreplicated barrel treatment had the smallest percentage of healthy roots, the largest percentages of roots decayed both at the neck and on the body of the root, and the smallest percentage of shriveled roots. Such results, although not significantly different from those on other lots, are what might be expected. The barrel afforded no ventilation and probably had conditions of humidity and temperature more favorable to decay than were prevalent in the small, ventilated boxes. On the other hand, such conditions would help maintain turgidity in healthy roots.

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[1] Platenius, H. physiological and chemical changes in carrots during growth and storage. N. Y. (Cornell) Agr. Expt. Sta. Mem. 161, 18 pp., illus. 1934.

Table 4.—*Condition of carrot stecklings after storage for 4 months at Logan, Utah, 1944–45, in an earthern-floor cellar, at a temperature around 40° F. and an average relative humidity of 80 percent*

Steckling size (diameter)	Condition of stecklings [1]			
	Healthy	Decayed		Shriveled
		At neck	Entire root	
	Percent	*Percent*	*Percent*	*Percent*
Small, ½–1 inch	66. 0	26. 1	4. 6	3. 2
Medium, 1–1½ inches	57. 5	29. 0	5. 6	8. 0
Do.[2]	63. 4	33. 6	1. 0	2. 0
Large, 1½–2 inches	66. 6	28. 5	2. 5	2. 5
Medium, 1–1½ inches [3]	51. 4	40. 0	7. 8	. 8

[1] Based on 4 replications, except for medium-size roots in barrel.
[2] Buried in sand.
[3] 500 roots, but no replications; in barrel.

COMPARISON OF TURGID AND SHRIVELED STECKLINGS

Methods

In commercial practice, stecklings sometimes become shriveled and pliable between the time they are taken out of storage and the time they are planted. Similar material was obtained by exposing normal stecklings to the sun and wind for about 3 days. In 1945 and in 1946, shriveled and turgid carrot stecklings were set out in separate plots in order to determine what stands could be obtained from such material. To ascertain whether the watering in of shriveled roots would increase the stands, approximately 1 pint of water was poured around half of the turgid and half of the shriveled roots in every plot. No irrigation water was available for approximately 6 weeks after the stecklings were set out. In 1945, planting was delayed until early May, when the soil was somewhat dry and air temperatures were higher and less favorable for the establishment of the roots than they had been in late March or early April. In 1946, the planting was made in the third week of April.

RESULTS [2]

The turgid roots produced better stands than shriveled ones, especially in the medium and small sizes (table 5). The stands from the medium-size and small shriveled stecklings were practically doubled by watering in at transplanting, but such stands were still poor. Turgid roots transplanted without water gave better stands than shriveled ones with water, regardless of root size. The best stands were obtained with large roots, which showed no response to watering in, when either turgid or shriveled. Small to medium-size shriveled roots produced such poor stands as to be of dubious value for transplanting.

TABLE 5.—*Stands obtained with turgid and shriveled stecklings planted with and without water, in terms of percentages growing by midsummer*

Type of steckling and method of planting	Stands obtained in—		
	1945	1946	
	Medium	Small	Large
Turgid roots:	*Percent*	*Percent*	*Percent*
With water	81. 25	93. 75	98. 03
Without water	77. 50	83. 75	98. 03
Shriveled roots:			
With water	47. 50	42. 50	82. 24
Without water	27. 50	20. 00	82. 29

RELATION OF STECKLING SIZE TO SEED PRODUCTION

METHODS

Preliminary studies of the effect that size of stecklings might have on the production of seed were begun in 1944 and 1945. Small, medium-size, and large roots planted both in the fall of 1944 and the spring of 1945, in single-row plots 50 feet long, were used. All stecklings in this test and later tests were set out 1 foot apart in plots randomized in four blocks. In the spring of 1946, the study was expanded to include stecklings of four sizes—very small, having a maximum diameter of less than ½ inch; small, ½ to 1 inch; medium, 1 to 1½ inches; and large, 1½ to 2 inches. Plots were 40 feet long and consisted of three rows spaced 3 feet apart. The center row of each plot was used for the record.

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[2] HAWTHORN, L. R., and POLLARD, L. H. VEGETABLE SEED PRODUCTION INVESTIGATIONS. Utah Agr. Expt. Sta. Farm and Home Sci. 7 (3): 8–10, 12, illus. 1946. Available only in libraries.

The size-of-root experiments in 1947 to 1949 included a group of very large stecklings which were more than 2 inches in diameter and, in addition, the plots contained four rows. A time-of-harvest experiment was superimposed on the size-of-steckling test. One of the two center rows was harvested early and the other late; the two outer rows served as guard rows.

NOTES ON PLANT HABIT

Although carrot plants from stecklings of a given size usually present a strikingly uniform appearance in height and general branching habit in any 1 year, notes were taken on these characters in most of the years. A plant of the predominant height was measured to determine the mode, and the extremes of height in healthy plants were recorded as the range. Similarly, branching habit was recorded by the range and mode of the number of main branches observed on the plants of a given plot or treatment. Only the modal measurements are presented here.

CLEANING AND TESTING THE SEED

The yields here reported are based on the weight of recleaned seed. In every experiment involving a seed harvest, conditions were made comparable to commercial threshing by the use of the Utah small thresher.[3] After threshing, the seed was "recleaned" with the smallest models of commercial screening and gravity mills obtainable. Since 1948, a four-screen, two-fan modern mill has been used for screening and fanning. Each lot has then, by the use of a deck reducer,[4] received the final milling over a gravity separator. After such a procedure, which is comparable in every way to conditions in commercial cleaning plants, it is believed that the seed really represents the type of seed that would be obtained in commercial practice.

A sample for the germination test[5] was taken from each experimental lot of seed with a Boerner sampler.

STATISTICAL ANALYSIS OF DATA

All the experiments involving yields of stecklings or of seed were designed so that a statistical analysis, usually of variance, could be made of the data collected. The conclusions are based on these analyses. In a number of tables, least significant differences have been indicated wherever they will aid in an understanding of the results.

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[3] HAWTHORN, L. R. SUCCESSFUL SMALL THRESHER. Seed World 64 (3) : 28, 30, 46, illus. 1949.

[4] HAWTHORN, L. R., POLLARD, L. H., and DRAPER, R. P. A DEVICE FOR HANDLING SMALL EXPERIMENTAL SEED LOTS ON A GRAVITY SEPARATOR. Amer. Soc. Hort. Sci. Proc. 54: 339–341, illus. 1949.

[5] All germination tests were made under the direction of E. H. Toole, senior physiologist, Division of Vegetable Crops and Diseases, Plant Industry Station, Beltsville, Md. The seed was germinated according to the rules and regulations of the Federal Seed Act and the rules of the Association of Official Seed Analysts.

RESULTS

EFFECT OF STECKLING SIZE ON NEW LEAF GROWTH

In the fall of 1944 and the spring of 1945, a few observations were taken on the number of small, medium-size, and large stecklings showing new leaf growth within 4 to 6 weeks after being set out. They show (table 6) that the larger the steckling, the greater the number that produce new leaves. These results show the same trend as percentage of stand (table 5). Observations in later years showed that the larger the root, the more easily good stands were obtained. Early growth of new leaves and 100-percent stands were often obtained with very large (more than 2 inches in diameter) stecklings when plots of very small (less than ½ inch) and small roots would have to be partially replanted for adequate stands.

TABLE 6.—*Proportion of Red Core Chantenay carrot stecklings, showing new growth 4 to 6 weeks after planting, 1944–45* [1]

Steckling size (diameter)	New growth on stecklings planted on—	
	Oct. 5, 1944	Apr. 19, 1945
	Percent	*Percent*
Small, ½–1 inch	30. 4	64. 2
Medium, 1–1½ inches		90. 0
Large, 1½–2 inches	65. 6	99. 2

[1] Records taken 4 weeks after planting in the fall, 6 weeks after planting in the spring.

EFFECT OF STECKLING SIZE ON RATE OF GROWTH OF INFLORESCENCE AND DEVELOPING SEED

The size of the carrot steckling when transplanted had a marked effect on plant development, including dates of appearance of the first flower buds, the first open flowers, full flowering, and maturity of the seed (table 7). The larger the steckling, the more rapid the rate of development. Full bloom and seed maturity were about 2 weeks earlier from very large than from medium-size roots and 2 weeks later from very small than from medium-size roots.

When stecklings were planted as early as feasible each spring, there was little variation from year to year in the time of each stage of development of plants from stecklings of a single-size group. For example, plants from medium-size stecklings reached seed-harvest stage between September 3 and 10 each year when grown by ordinary cultural methods.

The larger the steckling planted, the earlier flowering and seed formation take place. Most of the difference in time of development resulted from difference in time of starting growth and in time of

Table 7.—*Average dates at which carrots form buds and flowers and are ready for seed harvest at Logan, Utah*

[Based on observations during the years 1945 to 1949]

Steckling size (diameter)	First buds	Flowers open		Ready for harvest
		First	General	
Very small, <½ inch	June 12	June 24	July 16	Sept. 18
Small, ½–1 inch	June 4	June 16	July 9	Sept. 14
Medium, 1–1½ inches	June 1	June 12	July 2	Sept. 7
Large, 1½–2 inches	May 28	June 8	June 26	Aug. 28
Very large, >2 inches	May 24	June 3	June 18	Aug. 20

forming the first flower buds. The first flower buds and first open flowers developed from very large stecklings approximately 3 weeks earlier than from the very small ones. After the first flowers opened, however, the length of time to harvest was only about 1 week shorter among plants from very large roots than from those developed from very small ones.

It is difficult to determine when carrot plants reach general, or full, bloom because of the successive and overlapping flowering of the first-, second-, and third-order inflorescences on the main axis, which are borne on the central, secondary, and tertiary branches, respectively. The date of general bloom, as referred to here, is the time at which many of the second-order heads are in bloom, in addition to the flowers in the central head.

SIZE OF STECKLINGS AND EXTENT OF SEED SET

During the years 1946 to 1948, inclusive, estimates were made each year of the extent to which flowers in the various orders of umbels set seed. The conclusion was drawn that flowers in the first-order heads in healthy plants of all sizes set seed nearly 100 percent. This seemed to be true, also, for most of the second-order heads, even in plants from very small stecklings. Flowers in the third-order heads always set less seed—usually much less in the very small plants. In the third-order heads of the smallest plants, the average number of flowers setting seed in 1948 was as low as 60 percent, but, in 1946 and 1947, 80 to 85 percent of them seemed to produce seed. At the other extreme, similar flowers on the very large plants set at rates of 90 percent in 1948 and as high as 95 percent in the other years. The performance of the flowers in third-order umbels of plants grown from small, medium-size, and large roots was intermediate between that for the very small and that for the very large, with a tendency always for the percentage of setting to become higher with each increase in steckling size.

All of the observations were taken on plants grown 1 foot apart in rows 3 feet apart. Spacing has a tremendous effect on the numbers of flowers that set seed. Incidentally, the percentage of flowers that set seed should not be confused with the quantity of seed harvested from a head; heads vary greatly in size.

EFFECT OF STECKLING SIZE ON PLANT HABIT

When carrot plants were spaced as wide as 1 foot apart in rows 3 feet apart, the size of steckling often had a noticeable effect on both the height and the number of branches (table 8). From 1946 to 1949, plants grown from medium-size stecklings at Logan had a modal height of 34 to 48 inches with a 4-year average of approximately 3 feet. The modal number of main branches on the same plants was about 9. Plants grown from very small (less than ½-inch diameter) stecklings were always shorter and had fewer branches than plants grown from larger stecklings. In general, the larger the steckling, the taller the plant and the more branches it will produce.

TABLE 8.—*Height and branching in Red Core Chantenay carrot plants grown for seed in 3-foot rows and spaced 1 foot apart in the row, 1946–49*

Steckling size (diameter)	Average height of plants in—				Average number of main branches per plant in—		
	1946	1947	1948	1949	1946	1947	1948
	Inches	*Inches*	*Inches*	*Inches*			
Very small, <½ inch	24	36	24	27	6	6	6
Small, ½–1 inch	30	48	30	30	7	8	7
Medium, 1–1½ inches	34	48	33	36	9	9	8
Large, 1½–2 inches	34	54	36	39	11	10	9
Very large, >2 inches	36	54	36	39	12	12	9

Height of individual normal plants ranged from 21 inches, from some very small stecklings in 1946 and 1948, up to 60 inches, from large and very large stecklings in 1947. Main branches ranged from 4 to 19.

YIELD OF SEED AS INFLUENCED BY SIZE OF STECKLING

The yield of seed per acre or plant varied greatly from year to year, depending on the weather, and also on the size of stecklings planted (table 9). The data for 1947 to 1949, inclusive, when a time-of-harvest experiment was superimposed on that for size of root, are given in table 10. Of the 5 years, 1945 and 1947 were probably the most nearly normal. A hailstorm was responsible for the low yields in 1948. In 1946 and 1949, unusually favorable soil and climatic conditions were probably responsible for the higher-than-average yields.

The data, in general, indicate that as the steckling size decreased from large to very small, the yield of recleaned seed per acre was decidedly decreased. Evaluation of the data is somewhat complicated by the fact that size of root had an effect on stand and in 1948, particularly, was also responsible for the failure of some plants to bolt, or to bolt too late to produce seed. Poor stands and nonbolting plants reduce the acre yield of seed. As these factors are influenced by size of steckling, they become part of the treatment effect.

Table 9.—*Yields of recleaned seed harvested from Red Core Chantenay carrot stecklings of different sizes, 1945–46*

Steckling size (diameter)	Recleaned seed per acre in—	
	1945	1946
	Pounds	*Pounds*
Very small, <½ inch	----------	463
Small, ½–1 inch	641	744
Medium, 1–1½ inches	754	1, 216
Large, 1½–2 inches	849	1, 352

Nonbolters—plants that remain vegetative instead of developing seedstalks and producing seed—appeared in appreciable numbers only in plots planted with very small stecklings and then only in 1 year. In 1948, of the very small roots that were planted and grew 18 percent failed to produce seed. In other years, the percentage of nonbolters was low, even in plots from very small stecklings. From small to very large stecklings the percentage of nonbolters was 4 percent to none.

The data here reported (tables 10 and 11) with data not reported here, such as an analysis of grams of seed per plant, indicate that some of the effect of steckling size on yield of seed per acre was associated with both loss of stand and the failure of some plants to produce any seed. Most of the effect of steckling size, however, was carried over into the actual production of seed per acre.

In 1946, there was a steady increase in seed yield, from 463 to 1,352 pounds per acre, as the steckling size was increased from very small to large. The 3-year average of the early harvests (table 10) showed the same trend; the yield increased from 285 pounds for the very small up to 951 pounds for the large, and even to an average of 978 pounds for the very large stecklings. Yields from very large stecklings were not consistently greater than those from large ones, and sometimes they were lower.

The following records indicate what yields may be expected from individual plants. Average yields of seed, in grams per plant, from early and late harvests combined were: Very small, 19.0; small, 25.7; medium, 29.7 (slightly more than 1 ounce); large, 31.2; and very large, 36.7. Plants grown from very small stecklings may under adverse conditions average as little as 8.5 grams of seed, while plants grown from very large stecklings may, under favorable conditions, yield at a rate as high as 70.0 grams (more than 2 ounces) of seed. Yields of plants grown from medium-size stecklings, on the other hand, ranged from 16 grams (slightly more than ½ ounce) per plant

TABLE 10.—*Acre yields of Red Core Chantenay carrot seed as affected by size of steckling and time of harvest, 1947–49*

Steckling size (diameter)	Recleaned seed per acre							
	Early harvests in—				Late harvests in—			
	1947	1948	1949	Average	1947	1948	1949	Average
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Very small, <½ inch	590	128	[1] 136	285	626	136	[1] 85	282
Small, ½–1 inch	686	343	644	538	701	294	508	501
Medium, 1–1½ inches	879	407	1, 125	804	665	478	1, 225	789
Large, 1½–2 inches	885	599	1, 370	951	648	592	1, 470	903
Very large, >2 inches	877	568	1, 488	978	675	573	1, 325	858
Average (all sizes)	771	409	953	711	663	415	922	667
L. S. D.[2] at odds 99:1	(3)	334	559		(3)	334	559	
L. S. D.[2] at odds 19:1	(3)	466	388		(3)	466	388	

[1] Low yield mostly an effect of poor stand rather than size of steckling. Stand was too poor to include results in analysis of variance.
[2] Least significant difference for effect of steckling size on yield; effect of time of harvest not significant in any year.
[3] Not significant.

TABLE 11.—*Effect of steckling size on proportion of stecklings planted that produced seed-bearing plants, 1947–49*

Steckling size (diameter)	Proportion of stecklings planted that developed into seed-bearing plants							
	Early harvests				Late harvests			
	1947	1948	1949	Average	1947	1948	1949	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Very small, <½ inch	68	53	[1] 12	44	69	61	[1] 20	50
Small, ½ to 1 inch	88	82	46	72	77	76	48	67
Medium, 1 to 1½ inches	89	84	81	85	92	89	79	87
Large, 1½ to 2 inches	89	96	93	93	87	98	95	93
Very large, >2 inches	91	92	91	91	86	91	62	80
L. S. D. at odds 99:1	20	12	30	----------	20	12	30	----------
L. S. D. at odds 19:1	15	9	21	----------	15	9	21	----------

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[1] Treatment not included in analysis in 1949, but, even so, significant differences existed between some of the other treatments that year.

in a poor year to more than 46 grams (about 1¾ ounces) in a good year.

YIELD OF SEED AS AFFECTED BY TIME OF HARVEST

To determine the probable effect of delayed harvest of seed on yield through loss by chattering, the two halves of the plots each year were harvested 1 to 3 weeks apart. The first harvest was made as soon as the seed in the main head was completely brown; the second when the second-order heads were also brown and some of the third-order heads well on the way to being fully mature. There were no significant differences in seed yield between the two harvests (table 10). Either excessive delay or premature harvest beyond the limits of the tests may, of course, be expected to result in a failure to obtain the highest proportion of good seed from a given stand of plants.

EFFECT OF STECKLING SIZE ON VIABILITY OF SEED

The germination percentages of the recleaned seed grown from stecklings of each size group for 1947–49 (table 12) show no significant differences in germination due to size of steckling. Germination was lower in 1948 than in the other years, however, possibly the result of hail injury.

DISCUSSION AND PRACTICAL CONSIDERATIONS

Although the steckling-production experiments provide fairly reliable indications of the trends that may be expected when changes are made in time of planting, in rate of seeding, or in width of planter shoe, they can hardly be used as a guide to the exact numbers of stecklings that might be harvested. Too many factors—soil texture, soil fertility, and viability of the seed sown, for example—vary with location. Unpredictable climatic factors, such as a beating rain that crusts the soil before seedling emergence, may make a decided difference between two plantings, even in the same year and in adjacent locations.

The yield for the general run of commercial conditions of stecklings obtained in the experiments was above the average. The numbers harvested, however, were actually much below the number of seeds sown. According to the Association of Official Seed Analysts,[6] there are approximately 23,417 carrot seeds in an ounce. This means that in 3.4 pounds there are around 1,273,900 seeds. The highest total number of stecklings obtained in 3 years from such a rate of sowing (table 1) was in 1947, when there were 514,800.

As the combined number of the most desirable stecklings, the medium and large sizes, increases as the rate of seeding is increased, high rates of seeding certainly seem the most practical. Rates equivalent to 10 to 14 pounds of seed per acre when the rows are spaced 12 inches apart do not seem too high, if a grower desires the largest numbers of medium-size and large stecklings possible in a given area.

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[6] ASSOCIATION OF OFFICIAL SEED ANALYSTS. RULES FOR TESTING SEEDS ADOPTED BY ASSOCIATION OF OFFICIAL SEED ANALYSTS. Assoc. Off. Seed Anal. No. Amer. Proc. (39th Ann. Meeting), pp. 23–57, illus. 1949.

TABLE 12.—*Percentage germination after 28 days, of Red Core Chantenay carrot seed grown from stecklings in 5 size groups, 1947–49*

Steckling size (diameter)	Germination from—							
	Early harvests				Late harvests			
	1947	1948	1949	Average	1947	1948	1949	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Very small, <½ inch	85. 0	69. 0	80. 6	78. 2	88. 2	68. 4	81. 9	79. 4
Small, ½–1 inch	85. 4	73. 8	85. 4	81. 5	86. 6	72. 9	84. 9	81. 4
Medium, 1–1½ inches	86. 6	73. 9	88. 6	83. 0	88. 2	73. 1	83. 0	81. 4
Large, 1½–2 inches	85. 4	72. 2	90. 2	82. 6	88. 8	74. 9	87. 2	83. 6
Very large, >2 inches	88. 6	73. 5	89. 0	83. 7	91. 4	72. 5	85. 9	83. 2
Average	86. 2	72. 4	86. 7	81. 8	88. 6	72. 3	84. 5	81. 8

There will be large numbers of small and very small stecklings at such rates of seeding, but these usually can be discarded in the harvesting operations. If a maximum rate of seed increase is desired, instead of optimum use of land and labor, seeding rates should, of course, be light.

Planting in early to mid-June is probably the most satisfactory procedure in the intermountain area. Every postponement of as little as 2 weeks will cut drastically the number of usable stecklings harvested. Observations suggest that planting much earlier will result in a greater production of large and even very large stecklings, without adding greatly to the number of medium-size ones, thus creating a storage problem unless the grower is prepared for and desires stecklings of such sizes.

The standard narrow planting shoe and the 2-inch shoe both seem satisfactory and practicable. With their use, the same numbers of usable-size stecklings are obtained, more than are obtained with the 4-inch shoe under these conditions.

Recent studies by Mann and MacGillivray [7] probably explain why, when no thinning is practiced, it is nearly impossible under practical conditions to obtain a crop of carrot roots of uniform size. Their studies show that the great variation in root diameter found in any one planting seems to be related more directly to time of germination than to the spacing between plants in the row. Their experiments, as well as those of several other workers to whose publications they refer, indicate that in any given lot of carrot seed, emergence may continue for 2, 3, and occasionally many more weeks after the first sprouts appear. Mann and MacGillivray showed that the small roots in a planting were usually ones that had emerged late and that their smallness was not necessarily the result of close spacing within the row. Their work also indicated "an extreme inherent variation in size among carrot roots even where differences in time of germination and spacing are small."

Poor stands may contribute to low seed yields. Since better stands are always more easily obtained from unshriveled stecklings, it is good practice to avoid exposing the stecklings that have been taken out of storage to any more drying conditions than can be avoided. If for some reason stecklings of less than 1½ inches in diameter have become shriveled and pliable before transplanting and irrigation water is not available, it may pay to pour a little water around each steckling after planting. Watering in, however, cannot be expected to insure as good a stand as might be obtained with turgid roots.

Better stands are usually more easily obtained with the larger stecklings, and up to and including stecklings of 1½ to 2 inches in diameter seed yields are likely to increase on both an acre and plant basis from their use. Stecklings larger than 2 inches in diameter cannot be depended on to give still larger seed yields.

From a practical point of view, the percentage germination of recleaned seed seems to be but little affected by the size of stecklings from which the seed plants are grown. Certainly there should be no concern over what the germination may be when stecklings of the normally used medium size, or larger, are planted.

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[7] MANN, L. K., and MACGILLIVRAY, J. H. SOME FACTORS AFFECTING THE SIZE OF CARROT ROOTS. Amer. Soc. Hort. Sci. Proc. 54: 311–318, illus. 1949.

In view of the inconsistent results in the time-of-harvest studies, the most practical procedure would seem to be to harvest when most of the second-order heads have turned brown. To wait longer may result occasionally in higher seed yields but, on the other hand, yields then may be reduced by shattering or for other reasons. In the intermountain area, the weather often becomes less favorable for harvesting and threshing after mid-September. Other factors being equal, then, early harvest is preferable to late.

SUMMARY

Stock seed of Red Core Chantenay carrot was sown in a series of experiments from 1945 to 1949 at Logan, Utah, to determine the effect of rate of seeding, time of planting, and width of planting shoe on the numbers and distribution by size of the stecklings produced. Many of the same stecklings were later used in other experiments to determine the effect of steckling size on stand, rate of plant development, height, branching habit, seed yield, and viability. A time-of-harvest treatment was also combined with some of the studies. From these experiments, the following conclusions have been drawn.

Within practical limits, it is almost impossible to produce in an unthinned seedbed a crop of carrot stecklings of uniform size. Although the proportion of medium-size roots may remain relatively stable within a series of treatments, greater numbers of larger roots are obtained only at the expense of producing fewer smaller ones. The reverse is also true. The largest numbers of suitable stecklings were obtained by sowing at about 14 pounds per acre in rows a foot apart in early to mid-June.

Plantings as late as July 29 prevented the development of many large stecklings, but plantings as early as June 4 did not prevent the appearance of some small stecklings at harvesttime.

The rate of seeding had a greater over-all effect on the total number of stecklings harvested, although not necessarily such a noticeable effect on their distribution by sizes. Rates of seeding as low as 3.4 pounds per acre in 12-inch rows did not eliminate entirely, or even effectively reduce in a practical way, the presence of small stecklings at harvesttime. Nor did a rate of seeding as high as 17.9 pounds prevent large stecklings from being produced.

Under favorable storage conditions stecklings of all sizes kept equally well.

The addition of a small quantity of water around each steckling at time of planting increased the stands obtained from small and medium-size stecklings, but not those from large ones. Addition of water was particularly effective for small and medium-size shriveled roots and is recommended when they have to be used.

The use of medium-size and large stecklings resulted in better stands of seed plants than did the use of smaller ones.

The larger the steckling from which a carrot seed plant is grown, the earlier the flower buds appear, flowers open, and seeds mature. A crop grown from very large stecklings in an average season in

northern Utah was ready for harvest around August 20, but a crop grown from very small stecklings was not ready until nearly a month later. The time of harvest for an average crop in which medium-size stecklings had been set out was usually between September 3 and 10.

The flowers in first- and second-order heads of carrot plants of all sizes, spaced 3 by 1 feet, normally set seed about 100 percent, but with third-order heads the percentage was always lower, from 90 to 95 percent, on plants grown from very large stecklings, to as low as 60 percent, on plants grown from very small stecklings.

The larger the steckling planted, the taller and more branched the mature plant. Plants grown from very small stecklings ranged in modal height from 24 to 36 inches and had about 6 main branches per plant, in 4 years; at the other extreme, plants grown from very large stecklings ranged from 36 to 54 inches in modal height, and had as many as 12 branches per plant, in 2 years.

Yields of recleaned seed on both an acre and plant basis increased as the stecklings increased in size from very small to large. The use of very large (over 2 inches diameter) stecklings usually did not increase the yield of seed above that from large (1½ to 2 inches diameter) stecklings; in fact, it sometimes decreased yield.

Late harvesting had no consistent effect on seed yields. From a practical point of view, harvesting when the second-order heads turn brown seems safest.

Steckling size had little effect on the viability of the harvested seed.

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